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Lafmejani, Saeed Sadeghi; Olesen, Anders Christian; Kær, Søren Knudsen

Publication date:
2016

Document Version
Publisher's PDF, also known as Version of record

Analysing Gas-Liquid Flow in PEM Electrolyser Micro-Channels

AALBORG UNIVERSITY DENMARK

Saeed S. Lafmejani, Anders C. Olesen, Søren K. Kær
Dept. of Energy Technology, Aalborg University, Denmark
ssl@et.aau.dk

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Introduction

One means of increasing the hydrogen yield to cost ratio of a PEM water electrolyser, is to increase the operating current density. However, at high current densities (higher than 1 A/cm2), management of heat and mass transfer in the anode current collector and channel becomes crucial and can lead to hot spots. Management of heat and fluid flow through the micro-channels play a great role in the capability of PEM water electrolysis when working at high current densities. Despite, many studies have been done on gas-liquid flows; still there is a lack of research on gas-liquid flows in micro-sized channels (hydraulic diameter of 1 mm) of PEM water electrolysis. Precisely controlling all the parameters that affect the gas-liquid flow in a PEM water electrolysis cell is quite challenging, hence a simplified setup is constructed consisting of only a transparent channel with a sheet of titanium felt as a permeable wall.

Test section

As illustrated in the figure, the test section consisted as a square channel (5mm width by 1mm depth in cross-section area and 94 mm in length) with one of its sidewalls permeable to gases. Water was fed using a small power controlled centrifugal water pump into the test section from the inlet, while the laboratory air in which was decompressed by a regulator was fed into the multiphase flow channel along the porous sidewall. The test setup was made of transparent Plexiglas for visualization. The permeable wall is a layer of 0.35 mm Titanium felt with the size of 94 mm x 10 mm.

Test setup

Experiments were carried out in the test setup that is schematically shown in the figures. DI-Water, pumped from a water tank, passed through a valve, a variable area flow meter, the test section, and eventually returned to the water tank. Simultaneously, the laboratory compressed air was passed through a pressure regulator, a valve, a flow meter and penetrated through the porous sidewall to the test channel from the air channel.

Flow visualisation

A Basler acA1300-30um USB 3.0 camera with a Sony ICX445 CCD sensor was employed to visualize flow pattern in the test section with a shoot speed of 30 frames per second at 1.3 megapixel resolution. A Pentax lens with the focal length of 12 mm and the f-stop of 1.2 were used to capture the whole length of the channel at once. A 10 W LED was used to meet the required lightning for capturing images. As shown in the figure, the reflected LED light from the wall brights up the gas-liquid flow within the channel.

Figures

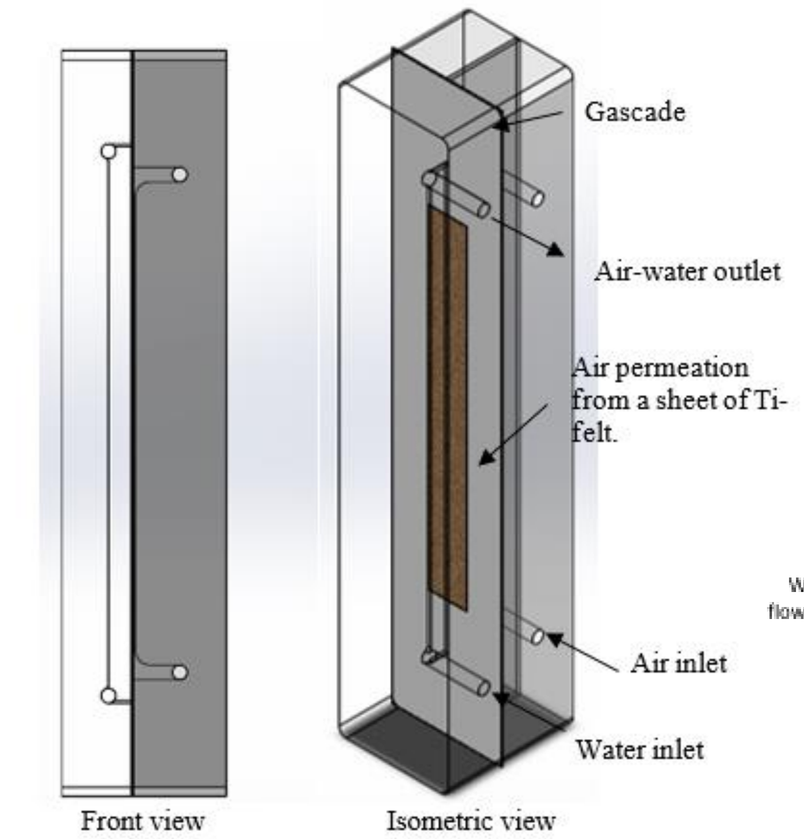
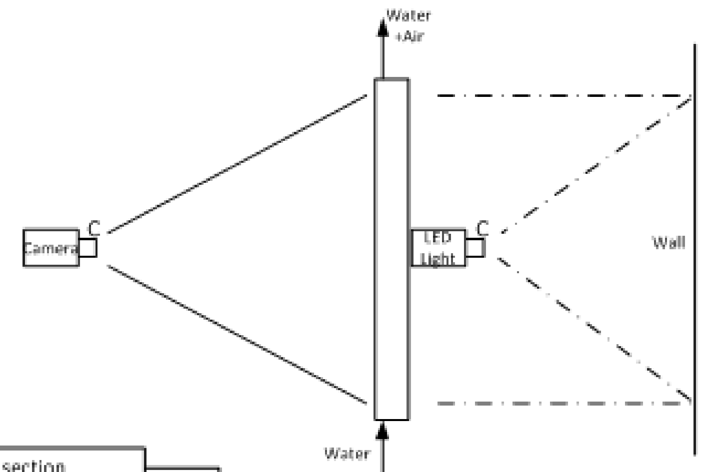
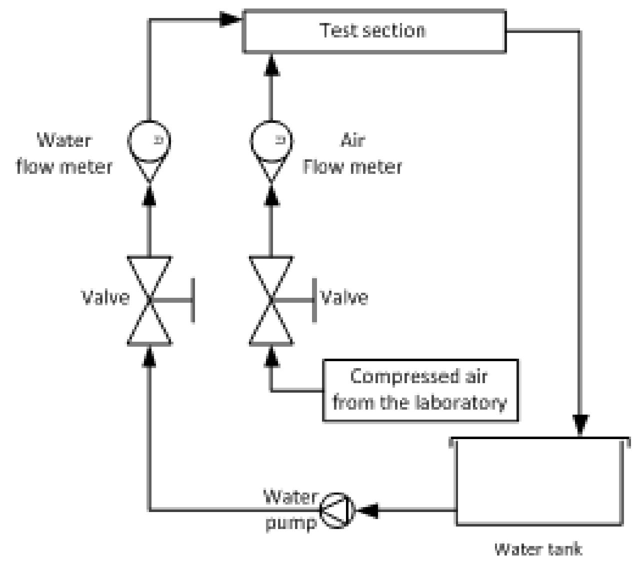
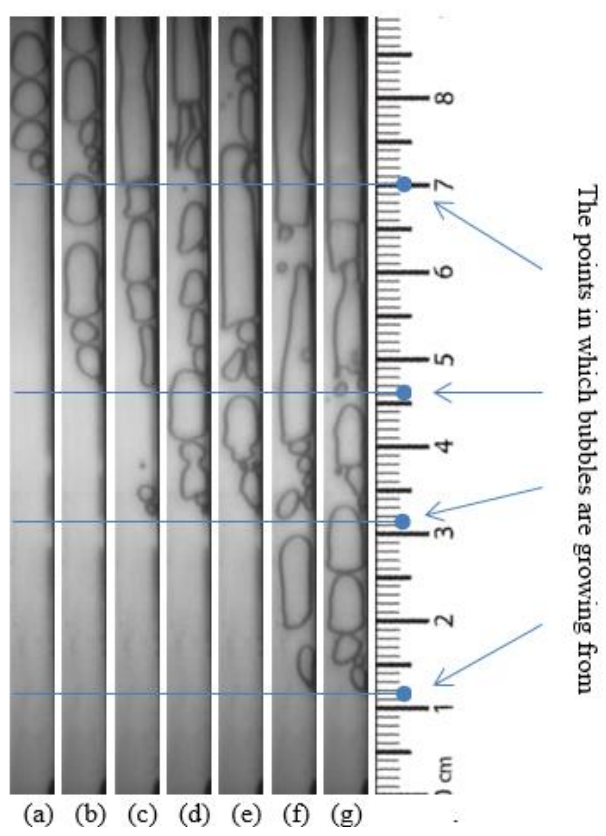
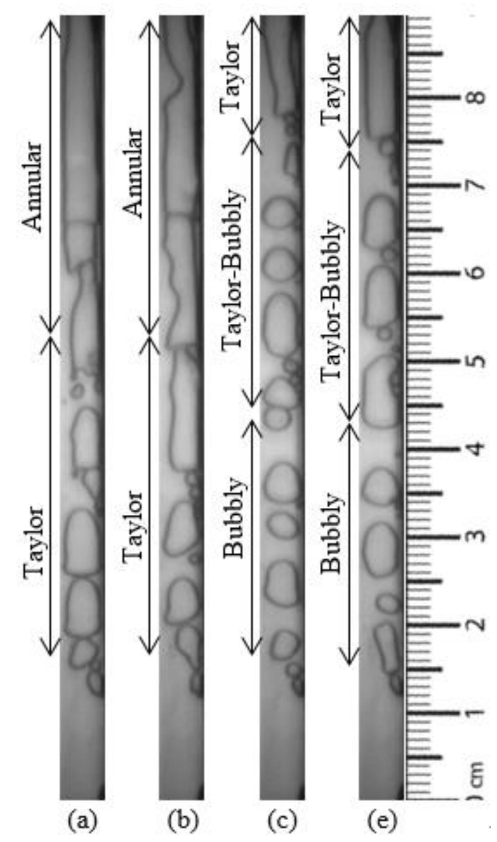


Figure 1: 3D view of the constructed transparent case.









Flow pattern

Bottom left figure shows grey scale images of the micro-channel for several water and air flow rates. (a) to (g) show images of the channel for a fixed flow rate of water 5.323 mL/min, while the air flow rate increased from 2.6 L/min to 31.2 L/min. As is shown, the air bubbles come out of the channel from specific points of the Ti-felt from top to bottom. As long as a single path offers the lowest pressure drop in the porous structure, air flows through this single rout and ignores the remaining cross-sectional area of the Ti-felt. By increasing the air flow rate, the pressure drop of the first rout increases. At a given pressure drop this then leads to another rout opening in the porous media to decrease the total air pressure drop. The growth of bubbles from specific points of the Ti-felt shows that the air flow in the saturated porous medium is highly capillary dominated, even at relatively high air flow rates found in high current density operation of electrolysers. Bottom right figure shows photos of the transparent channel in several air and water flow rates. The water flow rate doubled from (a) to (b) and the air flow rate also doubled from (b) to (c). Furthermore, to check reliability of the results, the air flow was made again by reducing from a high flow rate to the same as (c) to get the result of (d), which shows once penetration has been achieved the path will stay open.

Conclusion

- **Purpose of the study**: to investigate the mechanism of growth of bubbles from the Titanium-felt and their behaviour in the micro-channel instead of studying an electrolysis cell which is subject to complex electrochemical phenomena that affects the control of the test parameters.
- Observed gas-liquid flow regimes: bubbly-Taylor flow, Taylor flow and annular flow.
- Along the channel length coalescence of bubbles was observed.
- **Encountered problem**: due to the non-uniform structure of Ti-felt pores, a uniform bubble growth from the surface was not seen. Instead, bubbles grew from specific points of the Ti-felt that had larger pores.
- **To continue the research**: in this area and to improve the analysis, a layer of high flow resistant porous media with uniform Micro-pores might be added. This presumed to result in growth of a more uniform layer of bubbles from the Ti-felt surface.